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DETERMINATION OF THE AREAS OF MAXIMUM STRESS DURING THE DONNING AND DOFFING OF CLOTHING

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ABSTRACT

This paper examines the donning and doffing process for the Canadian Forces combat shirt, trousers and coveralls in order to identify the areas of maximum stress during donning and doffing. It was found that the greatest stress occurs across the back of the shirt or coverall top on donning when both arms are partially into the sleeves and the garment back is stretched between the two elbows.

RÉSUMÉ

Le présent document examine le processus de revêtement et d'enlèvement de la chemise, du pantalon et des combinaisons de combat des Forces canadiennes afin de repérer les endroits où ces vêtements offrent le plus de résistance lorsqu'il s'agit de les endosser ou de les enlever. Les résultats de cet examen ont révélé que la plus grande résistance se produit en travers du dos lorsqu'on endosse la chemise ou le haut de la combinaison et ce, notamment lorsque les bras sont partiellement allongés dans les manches et que la partie arrière du vêtement est tendue entre les deux coudes.

INTRODUCTION

We had undertaken a study to determine where maximum stress occurred in typical Canadian Forces (CF) combat clothing. In the first phase of this study, we had identified the areas of maximum stress in a shirt, trousers and coveralls during wear and the stances which cause these stresses (Crow and Dewar, 1984). We found that crossing the arms in front with the hands on opposite shoulders creates the greatest stress in the shirt or coverall top and squatting creates the greatest stress in the trousers and coverall bottoms, this occurring along the upper, inner leg and the crotch area. Since seams can fail during donning and doffing, we continued our study by examining the donning and doffing procedures for the CF combat shirt, combat trousers and aircrew coveralls to identify the probable areas of maximum stress during these procedures. This paper reports the results of this study.

METHOD

In the earlier study (Crow and Dewar, 1984), a subject had worn specially-made slit-rubber sheeting clothing, the slits of which gaped under stress to show clearly stress patterns for various stances, as illustrated in Figure 1. Considerable care had to be taken in donning and doffing the rubber clothing since it was quite easy to get the hands or feet caught up in the readily-extensible slit 'fabric'. Further, it was found that the rubber sheeting deteriorated over a relatively short time

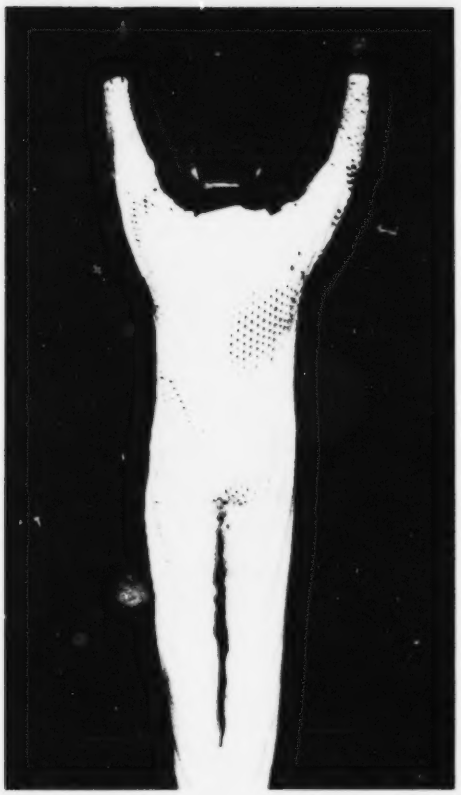

Figure 1: Stress patterns in the slit-rubber sheeting coveralls. Half of the garment has the slits running vertically and half running horizontally to detect the vertical and horizontal stresses.

and ripped quite easily. Therefore, actual CF clothing (shirt, trousers and coveralls) was used in this study and careful observations were made for the areas of stress.

Initially we videotaped from the front, back and side five male subjects donning and doffing the clothing. The videotape was examined in slow motion and the step-by-step motions of donning and doffing the clothing observed for each subject. These observations were compiled and appropriate stills reproduced for the purpose of this report.

The subjects were members of the Canadian Forces and used their own issued clothing. Three of the subjects were right-handed, one left-handed and one ambidextrous. The subjects ranged in height and weight from 1.69 m and 59.2 kg to 1.78 m and 81.5 kg.

THE DONNING AND DOFFING OF THE TROUSERS

Donning

The sequence for donning the trousers is shown in Figures 2 to 8.

Doffing

The sequence for doffing the trousers is shown in Figures 9 to 13.

Figure 2: The subject holds the trousers in front of him.

Figure 3: He then bends forward, bending the leg to be put into the trouser leg and puts the foot into the trouser leg.

Figure 4: He straightens up the body with the hands in the trouser waist and pulls the trousers up to his waist. This allows the foot to go through the trouser leg.

Figure 5: The subject then bends forward again, allowing the trousers to drop to the knees and starts to insert the second leg into the trouser leg.

Figure 6: The second leg is now in the trouser leg.

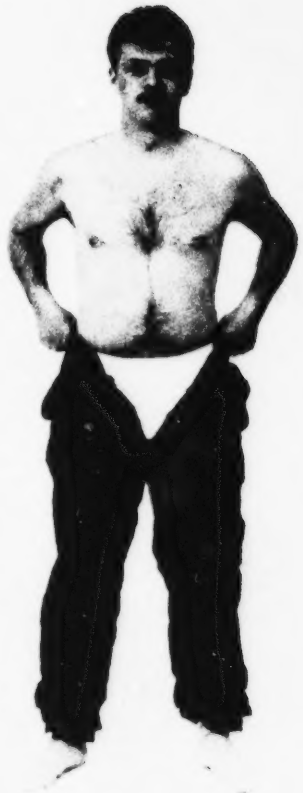

Figure 7: He then moves the hands to the trouser side back and pulls the trousers up over the hips.

Figure 8: The centre front is pulled together and fastened. The trousers are donned.

Figure 9: The subject unfastens the trousers, parts them at the front and then moves the hands to the side of the trouser waist and pushes the top of the trousers down over the hips.

Figure 10: Since the combat trousers are quite loose fitting, they fall quite readily to the floor.

Figure 11: He then steps out of the trousers.

Figure 12: Alternatively, he bends forward, reaches down to grasp each trouser bottom in turn and pulls the trouser leg off the foot.

Figure 13: The trousers are doffed.

THE DONNING AND DOFFING OF THE SHIRT

Donning

When we viewed the video pictures, we found that there were, in general, two common ways of donning a shirt, the two-armed donning and the one-armed donning. The two-armed donning is shown in Figures 14 to 19 and the one-armed donning in Figures 20 to 25. A variation of the one-armed method is shown in Figures 26 to 29. Often the military have to don clothing in a confined space such as a tank or a crowded tent. In these conditions, the shirt may be donned in a vertical rather than a horizontal fashion, as shown in Figures 30 to 32.

Doffing

The sequence for doffing the shirt is shown in Figures 33 to 35.

Figure 14: For the two-armed donning, the subject first takes the shirt by the neck with both hands.

Figure 15: He then starts to rotate one arm over his head, the shirt swinging to the side.

Figure 16: When the arm is over his head, the shirt has swung to the back. The other arm begins to enter the sleeve.

Figure 17: When the one arm has entered the sleeve, the subject puts the free arm into the sleeve and either raises it to allow the sleeve to slide down the arm or reaches it out to the side, putting the arm through the full length of the sleeve.

Figure 18: The next movement, common to all ways of putting on the shirt and to all subjects, is to adjust the collar and so, the shirt back.

Figure 19: The final movement is to close the shirt front. The shirt is donned.

Figure 20: For the one-armed donning, the subject holds the shirt in front of him.

Figure 21: He then puts an arm into the sleeve.

Figure 22: He reaches around to the back with the other arm, grasps the shirt and starts to find the armhole.

Figure 23: The subject puts the arm through the sleeve.

Figure 24: He adjusts the collar, and thus the shirt back.

Figure 25: He fastens the shirt front and the shirt is donned.

Figure 26: In a variation of the one-armed method, the subject lets the shirt hand on one hand.

Figure 27: He swings the shirt behind the back and catches it with the free hand.

Figure 28: He puts the first arm completely into the sleeve, then the second arm.

Figure 29: With a shrug of the shoulders, he moves the shirt onto them.

Figure 30: The subject places the shirt before him with the front down and puts the arms into the sleeves.

Figure 31: He then raises his arms over his head.

Figure 32: He allows the shirt to drop behind the body so that the arms completely enter the sleeves.

Figure 33: To doff the shirt, the subject first slips the shirt off of one shoulder.

Figure 34: He then slips the shirt off the other shoulder.

Figure 35: He then usually allows the shirt to slip off the arms and to the floor. Alternatively, he uses the hands to assist in the removal of the shirt as will be shown in doffing the coveralls in Figure 44.

THE DONNING AND DOFFING OF THE COVERALLS

Donning

The method for donning the coveralls was similar for all subjects and is shown in Figures 36-40.

Doffing

The sequence of doffing the clothing is shown in Figures 41 to 46.

Figure 36: The subject begins donning the coveralls in a manner similar to that of donning the trousers by stepping into each leg in turn.

Figure 37: The coveralls are pulled to the waist.

Figure 38: To don the upper part of the coveralls, the subject reaches back to put one arm into the sleeve to the elbow and repeats the motion with the second arm.

Figure 39: He then shrugs the shoulders to get the coveralls onto one or both of them.

Figure 40: He then takes the collar and adjusts the coveralls, removing the stress from the coverall back.

Figure 41: To doff the coveralls, the subject first pulls the coveralls off of one shoulder.

Figure 42: He then shrugs the coveralls completely off the shoulders.

Figure 43: With the hands behind the back, he pulls the sleeve cuff over the hand, freeing one arm from its sleeve.

Figure 44: Moving the hands to the front, he pulls the other sleeve cuff over the hand to free the second arm.

Figure 45: The subject lets the coveralls drop to the knees.

Figure 46: He removes the trouser portion of the coveralls as he did with the combat trousers.

Figure 47: Greatest observed area of stress in donning and doffing clothing

OBSERVED AREAS OF MAXIMUM STRESS

The greatest observed area of stress in donning and doffing the clothing was across the back of the shirt or coveralls when both arms were partially into the sleeves and the shirt or coverall top was not yet on the shoulders, as shown in Figure 27 or 38. A back view of Figure 28 is shown in Figure 47. Here the elbows act as tie points and the shirt or coverall top is stretched between them.

No great stress was readily evident in the donning and doffing of the trousers. The only conceivable way that high stress might occur in the loose-fitting combat trousers would be for a foot to get caught in the trouser leg during donning. This would cause stress along the longitudinal trouser seams. Similar stress could be caused if the subject donned or doffed the trousers wearing footwear. The designers of CF combat clothing are aware of this possibility and design CF combat trouser leg widths accordingly. In general, the width of the CF combat trouser leg is narrow enough to discourage attempts to force a combat boot down through it.

GENERAL COMMENTS

In subsequent work (Crow and Dewar, 1985), it was found that there was more stress exerted on the clothing in wear than in normal donning, the closer fitting the clothing on the subject, the greater the stress in the clothing. The handedness of a subject was not necessarily reflected in his method of donning or doffing clothing and had no effect on the generated stresses.

CONCLUSION

The maximum stress encountered in normal donning and doffing of clothing occurs across the back of the shirt or coverall top in donning when both arms are partially into the sleeves and the garment is stretched between the tie points of the two elbows.

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Crow, R.M. and Dewar, M.M. (1985). The Magnitude of Maximum Stress in Clothing.
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